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Claims

[c1] 1. A method for leak-before-rupture assessment, the method comprising:
using a failure assessment diagram (FAD) assessment curve from a crack initiation based FAD analysis to analyze a crack in a material; and
using a ductile tearing analysis in conjunction with the FAD assessment curve to detect a crack exhibiting at least one of ductile tearing stability and tearing instability prone to rupture during growth of the crack.

[c2] 2.The method of claim 1, wherein the ductile tearing analysis takes into account an increase in a material fracture toughness during the crack growth.

[c3] 3.The method of claim 2, further comprising:
using a J-integral approach to describe an elastic-plastic fracture behavior of the material having the crack,
wherein J_{app} = a driving force for the crack growth, and
J_{mat} = a material resistance to the crack growth.

[c4] 4.The method of claim 3, wherein the tearing instability criteria indicative of a rupture include

$$J_{app} > J_{mat} \text{ and } \frac{\partial J_{app}}{\partial a} > \frac{\partial J_{mat}}{\partial a}.$$

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[c5] 5.The method of claim 4, wherein the crack growth is stable when

$$J_{app} \leq J_{mat} \text{ and } \frac{\partial J_{app}}{\partial a} \leq \frac{\partial J_{mat}}{\partial a}.$$

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[c6] 6.The method of claim 5, wherein the ductile tearing analysis includes:

plotting the FAD assessment curve;

calculating a stress ratio (L_r) and a ratio of

$$\sqrt{J_{app}/J_{mat}}$$

(K_r) for a range of crack growth increments (Δa) corresponding to assessment points; and
plotting the assessment points of Kr versus Lr for ductile tearing and tearing instability analysis.

[c7] 7.The method of claim 6, wherein L_r is a ratio of reference stress (σ_{ref}) to yield strength

$$(\sigma_y)(\text{i.e.,}\ \sigma_{ref}/\sigma_y),\ \text{said}\ \sigma_{ref}$$

is a function of applied stress and crack size.

[c8] 8.The method of claim 6, wherein said J_{mat} is derived from a J-R curve for the material resistance to the range of crack growth increments (Δa).

[c9] 9.The method of claim 8, wherein the J-R curve is experimentally established for the material at a temperature corresponding to an assessment temperature.

[c10] 10.The method of claim 6, wherein said J_{app} is calculated based on an applied load and a shape of the crack.

[c11] 11.The method of claim 6, wherein when the assessment points fall below the FAD assessment curve, the crack growth is stable and will not rupture at a constant operating pressure or applied load.

[c12] 12.The method of claim 6, wherein when all of the assessment points are disposed either above or tangent to the assessment curve, the crack growth is prone to failure by rupture at a constant operating pressure or applied load.

[c13] 13.The method of claim 6, wherein when all of the assessment points are disposed entirely below the FAD assessment curve, the crack growth is not present at a constant operating pressure or applied load.

[c14] 14.The method of claim 1, wherein the crack is one of a single crack and a crack field disposed in a pipeline.

[c15] 15.A method to detect leak-before-rupture cracks in a pipeline material that exhibits stable crack growth by ductile tearing, the method comprising:
using a failure assessment diagram (FAD) assessment curve from a crack initiation based FAD analysis to analyze a crack in a material; and
using a ductile tearing analysis in conjunction with the FAD assessment curve to detect a crack exhibiting at least one of ductile tearing stability and tearing instability prone to rupture during growth of the crack, wherein the ductile tearing analysis takes into account an increase in a material fracture toughness during the crack

growth.

[c16] 16.The method of claim 15, wherein the ductile tearing analysis includes:

plotting the FAD assessment curve;

calculating a stress ratio (L_r) and a ratio of

$$\sqrt{J_{app}/J_{mat}}$$

(K_r) for a range of crack growth increments (Δa) corresponding to assessment points; and

plotting the assessment points of Kr versus Lr for ductile tearing and tearing instability analysis.

[c17] 17.The method of claim 16, wherein L_r is a ratio of reference stress (σ_{ref}) to yield strength

$$(\sigma_y)(\text{i.e.,}\ {}^{\sigma_{ref}}/_{\sigma_y}),\ \text{said}\ \sigma_{ref}$$

is a function of applied stress and crack size.

[c18] 18.The method of claim 16, wherein said J_{mat} is derived from a J-R curve for the material resistance to the range of crack growth increments (Δa).

[c19] 19.The method of claim 18, wherein the J-R curve is experimentally established for the material at a temperature corresponding to an assessment temperature.

[c20] 20.The method of claim 16, wherein when the assessment points fall below the FAD assessment curve, the crack growth is stable and will not rupture at a constant operating pressure or applied load; when all of the assessment points are disposed either above or tangent to the assessment curve, the crack growth is prone to failure by rupture at a constant operating pressure or applied load; and when all of the assessment points are disposed entirely below the FAD assessment curve, the crack growth is not present at a constant operating pressure or applied load.